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3 - Terminal MTJ

3/9/24

The IDEA

MTJ Classification based on Magnetic Anisotropy

#MTJ → In-Plane → ⟷ → P2AP, AP2P

#MTJ → Perendicular → P2AP, AP2P

P2AP

parallel to Antiparalle

RL ↑ ➡ ↑
FL ↑ ➡ ↓ } P

RL → ➡ ←
FL → ➡ → } I

more current needed

↓

less desired

AP 2P

Antiparallel to Parallel

RL ↑ ➡ ↑
FL ↓ ➡ ↑ } P

RL → ➡ →
FL ← ➡ → } I

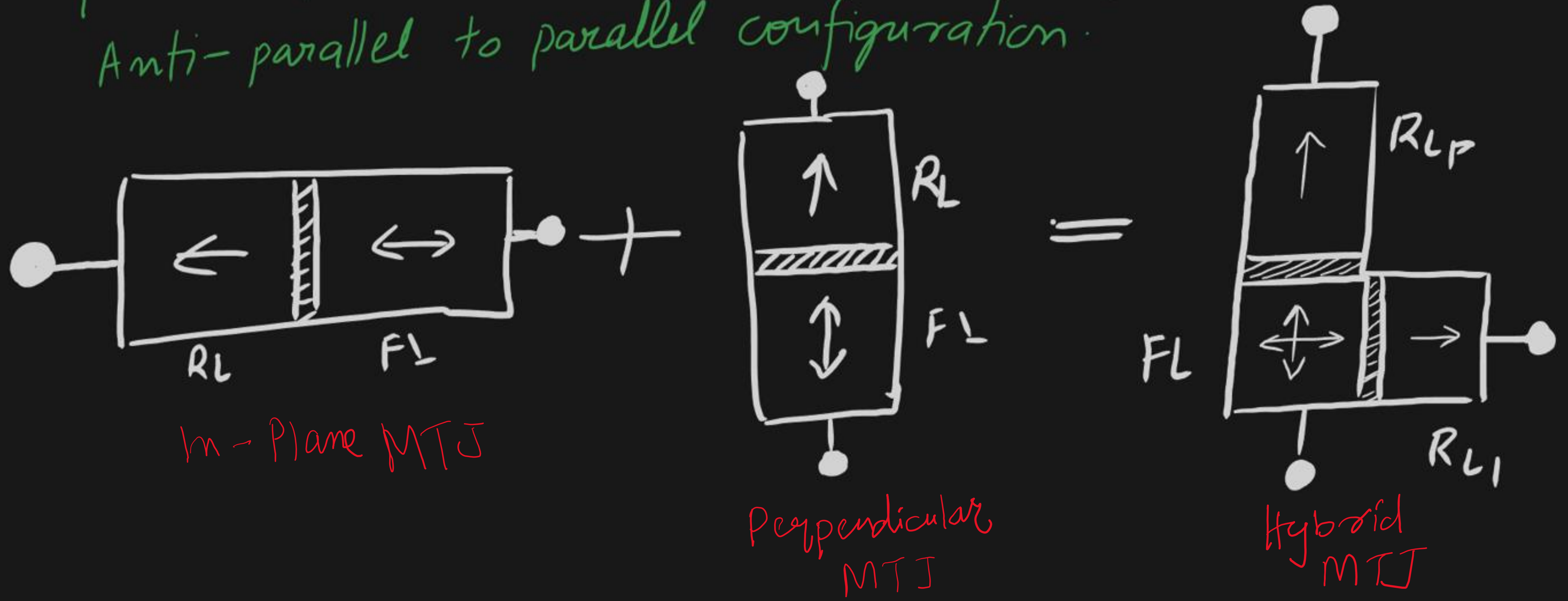
less current needed

↓

desirable condition

l
ntages
S.

The **IDEA** is to combine the pMTJ (perpendicular) and the iMTJ (in-plane) to get a HYBRID MTJ that switches from perpendicular to in-plane so as to only operate in Anti-parallel to parallel configuration.



Why?

Optimization of existing
CMOS – MTJ circuits

How?? → [1] Trying and always running the MTJ in AP {Anti-parallel} to P {Parallel} configuration.

⇓

CURRENT DEMAND drastically REDUCES

[2] Non-volatility
Better Processing speeds
Thermal stability

} general advantages of MTJs.

HOW

#

RL
FL

RL
FL

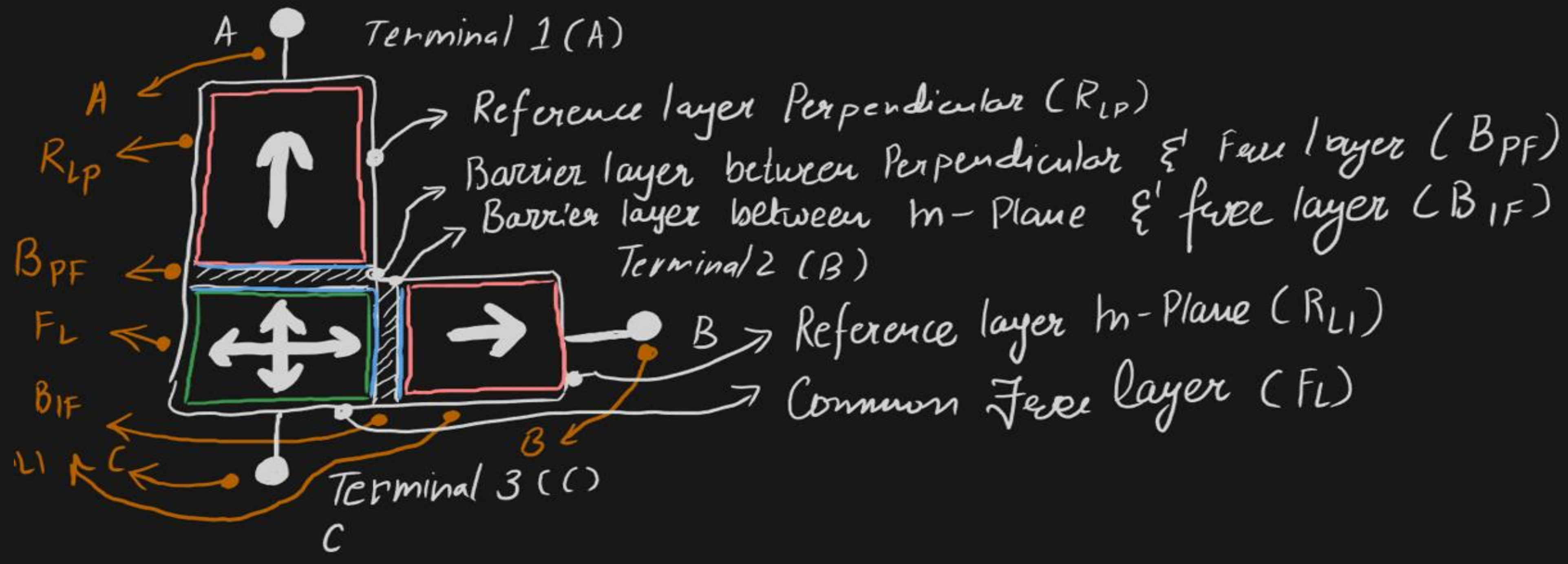
HOW

Better Processing speeds of MTJs:

Thermal Stability

Te

Proposed Structure :



→ Barrier layers → SEPARATE

→ Free layer → COMMON

→ Re-erence layers → SEPARATE

PROBLEMS :

1) LLGS equation only solves magnetization dynamics for either perpendicular OR in-plane.
∴ incorporating them to work together on a hybrid device needs significant changes

2) lets ignore peoblem 1 & assume the peoposed MTJ somehow works. Even if it switches states from AP to P with respect to pMTJ, in the immediate next switching cycle, the FL state in perpendicular configuration has to be modeled to be Anti-parallel with respect to iMTJ.

3) Corresponding read and write drivers / circuits.

4) Usage & Implementation of this in pre-existing circuits.

Potential Solutions

1) for peoblem 1,
lets say we divide LLG equat

1] for problem 1,
lets say we divide LLG equation into 2 components:

$$\boxed{LLG_{overall} = LLG_{perpendicular} + LLG_{in\text{-}plane}}$$

we can introduce a multiplication factor here and call it the "type" parameter. type = 1 → P type = 2 → I

Whenever p [perpendicular] is ON we want the i [in-plane] part to be off, and vice versa.

So, we can use MA in the equation above to selectively activate components.

↳ MA = type ⇐ same values

$$LLG_{overall} = \underbrace{\{[MA]\times[LLG_p]\}}_{} + \underbrace{\{[1-MA]\times[LLG_i]\}}_{} \rightarrow (1)$$

now, let's say we want the LLG to be solved for the instant where it operates in perpendicular configuration then type = 1,

Substitute in eq^{n} 1 :

$$LLG_{overall} = \cancelto{\text{finite}}{(1 \times LLG_p)} + \cancelto{0}{((1-1) \times LLG_i)}$$

$$\therefore LLG_{overall} = LLG_p$$

Similarly, if it is working in in-plane config :

type = 0,

$$LLG_{overall} = \cancelto{0}{(0 \times LLG_p)} + \cancelto{\text{finite}}{((1-0) \times LLG_i)}$$

$$\therefore LLG_{overall} = LLG_i$$

2] 2.1) Investigation into easy axis based switching

↳ ongoing

2.2) mapping P states to I states by developing some algorithm

1

Problem 3 & 4

→ ideal to look into post-model devlopment as they are circuital implementation concerns.

Thank you!